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Expert Report of Brian L. Murphy, Ph.D.

Prepared for Faegre & Benson, LLP

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Brian L. Murphy, Ph.D.

In the United States District Court
For the Northern District of Oklahoma

STATE OF OKLAHOMA, *ex rel,* W.A. DREW EDMONDSON in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT

O. MILES TOLBERT, in his capacity as the TRUSTEE FOR NATURAL RESOURCES FOR THE STATE OF OKLAHOMA,

Plaintiffs,

v.

TYSON FOODS, TYSON POULTRY, INC., TYSON CHICKEN INC., COBB-VANTRESS, INC., AVIGEN INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTS, LLC GEORGES, INC., GEORGES FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS, INC., AND WILLOWBROOK FOODS, INC.

Defendants

Case No. 05-CV-329-GKf-SAJ

Prepared for
Faegre & Benson, LLP

Prepared by

Brian L Murphy 1-27-09

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Exponent

Executive Summary

I have been retained by Faegre & Benson, LLP, on behalf of Cargill, Inc., in the context of litigation over poultry litter application to fields in the Illinois River Basin. Specifically, I was asked to examine Dr. Roger Olsen's report, affidavit, deposition testimony, and related documents in this case, in order to determine: (a) whether the data set used by Dr. Olsen for the Cargill contract turkey growers was sufficient to support the implication that they are responsible for determinable downstream concentrations; (b) whether the statistical analysis performed by Dr. Olsen, known as principal components analysis, or PCA—which leads him to conclude that poultry growers generally are a determinable source of downstream chemical and bacterial concentrations—was conducted and interpreted in an appropriate manner; and (c) if the statistical analysis were conducted in an appropriate manner, whether it supports a conclusion that any Cargill contract grower or any other grower is responsible for determinable downstream concentrations.

PCA is often used in environmental studies to determine which samples are similar—that is, appear to originate from a common source—and which samples are different, when the number of samples and the number of analytes (chemicals, bacteria, etc.) in each sample is too large to determine such relationships simply by inspecting the data. The output of PCA consists of a multidimensional loadings plot and a multidimensional scores plot. Analytes that occupy the same area of a loadings plot co-vary; that is, the concentration goes up and down in tandem from sample to sample. Samples that may represent different locations and media (soil, water, etc.) can occupy the same area of a scores plot, thus behaving as if they have a common source.

My principal conclusions are as follows:

- **Cargill contract grower data used by Dr. Olsen in his PCA are either too limited to draw conclusions or lead to conclusions that are opposite those drawn by Dr. Olsen.**

  - There are 35 Cargill contract growers in the Illinois River Basin. Dr. Olsen collected data at just two contract growers. At one Cargill contract grower, he collected only one turkey-litter sample and no environmental samples.

  - At the other contract grower location, Mr. Schwabe's farm, Dr. Olsen collected turkey-litter and some environmental samples, including two spring samples, a Geoprobe® groundwater sample, and soil samples at four locations. However, he did not use all of these data in his analyses. In part, this was because he was not able to detect a sufficient number of analytes—i.e., the samples were "too clean"—and in part for reasons that he fails to explain.

  - Dr. Olsen selected analytes that are commonly found in soil and elsewhere in the environment. He failed to select sufficient analytes that were specific to poultry litter or even to living organisms.

3 Plaintiff Sampling at Cargill Contract Growers' Locations

Sampling was conducted for only two Cargill contract turkey growers—Robert Schwabe and Clyde Masters.

At Masters' location, poultry litter was sampled by plaintiffs at only one station (FAC-14). One poultry litter sample was also analyzed from Schwabe's farm (FAC-08). Also from Schwabe's farm, two groundwater samples (LAL-16-GW-1 and LAL-16-GW-2), two spring-water samples (LAL-16-SP1 and LAL-16-SP2), one Geoprobe® groundwater sample (GP-GW-10), and soil samples at four locations (LAL-16A, LAL-16B, LAL-16C, and LAL16D) were collected. Soil samples were collected at the surface (0–2 inches) and subsurface (2–4 inches and 4–6 inches). Mehlich phosphorus was the only analyte measured in the 4- to 6-inch depth interval; 11 analytes were measured for the 0- to 2-inch depth at LAL-16A, and the 2- to 4-inch depth at LAL-16A, LAL-16C, and LAL-16D; and more than 34 analytes were measured for the 0- to 2-inch depth at LAL-16B, LAL-16C, and LAL-16D, and the 2- to 4-inch depth at LAL-16B.

Olsen's SD1 and SD6 analyses include only three of the soil samples from Cargill contract growers that had more than 34 analytes. All three are from the Schwabe farm, which covers approximately 592 acres, or nearly a square mile. Clearly, three samples are inadequate to characterize conditions across the entire Schwabe farm.

There are a number of subsurface soil samples that appear to have adequate data for inclusion in Olsen's solid materials runs (SD1 and SD6) but that were not used, including the fourth Schwabe sample with 34 analytes (2- to 4-inch depth at LAL 16-B[3]). The reasons for exclusion are not discussed in Olsen's report. The other (non-Cargill-related) samples appear to have detected results for virtually all of the analytes included in Olsen's analyses; therefore, the presence of too many non-detect results does not seem to justify exclusion. These samples include LAL-2A-4, LAL-2A-6, LAL-3A-4, LAL-3A-6, LAL-3B-4, LAL-3B-6, LAL-10A-4, LAL-15B-4, LAL-15B-6, CL-1A at depth, CL-1B at depth, CL-2A at depth, and CL-2B at depth. The CL- samples are reference soil samples. Including them would have shed more light on the variability of background sample compositions.

In addition to samples being excluded without justification, there is some discrepancy in the identification for Cargill contract grower samples from location LAL-16B. Olsen's spreadsheet of results identifies sample "LAL-16B 7/17/2006:SL:S:2:-" as subsurface soil in a column labeled EDA_Group ("SD-Soil-Subsurface"). This also occurs for one other sample (LAL-5D:6/12/2006:SL:S2:-) in both his SD1 and SD6 analyses. Both samples have sample names that indicate they are from the 0- to 2-inch depth interval (sample names ending in 2) (i.e., not subsurface). By elimination of other possibilities, the sample from LAL-16B is probably a surface soil sample. The 2-to 4-inch sample taken at LAL-16B on 7/17/2006 had only 13

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3 Other subsurface samples at LAL-16A, LAL-16C, and LAL-16D do not meet Olsen's selection criteria for PCA, because too few analytes were measured.

analytes measured, and the 4- to 6-inch sample had only one analyte measured; thus, both were not suitable for inclusion in analyses. Interpreting this as a surface sample is consistent with Dr. Olsen's descriptions of his SD1 and SD6 analyses in his produced PCA_Solids_Runs_Table(2).xls file.

At neither the Schwabe nor the Masters locations were any edge-of-field samples collected. Thus, a critical link in Dr. Olsen's transport theory is missing.

As with soil samples, not all of the samples collected in other media were used in Olsen's water analyses that form the basis of his report (SW3, SW17). The only two groundwater samples associated with Schwabe's farm were excluded, because they had too few analytes detected to meet Olsen's inclusion criteria. This, in itself, indicates a lack of significant poultry litter–related concentrations. Except for the one Geoprobe® groundwater sample from Schwabe's nearly one-square-mile property, no groundwater samples from Cargill contract growers enter his analyses. Thus, the Cargill contract growers are inadequately characterized or not characterized at all, and a second critical link in Dr. Olsen's transport theory is missing.

Table 3-1 summarizes the samples from Cargill contract growers included in Olsen's analyses:

Table 3-1. Summary of samples from Cargill growers used in Dr. Olsen's analyses

Sample Type	Grower	
	Schwabe	Masters
Poultry Litter	FAC-08	FAC-14
Surface soil	LAL-16B, LAL-16C, LAL-16D	-
Edge of field	-	-
Groundwater(Geoprobe®)	GP-GW 10	-
Springs	LAL-16-SP1, LAL-16-SP2	-

3.1 Comparison of Cargill Contract Grower Samples to Other Samples

3.1.1 Cargill Contract Grower Solid Samples

Olsen provides plots of his solid sample analyses, including poultry litter and soil, in his Figures 6.11-20c (run SD1, PC1 vs. PC2), 6.11-20e (run SD1, PC2 vs. PC3), and 6.11-21c (run SD6, PC1 vs. PC2). These figures are reproduced in this report, with the Schwabe and Masters samples and locations downstream or downgradient of Cargill contract growers identified, as

Figures 3-1, 3-2, and 3-3. Reference (background) sample locations have also been identified. These figures show the Varimax rotation results for SD1 and the non-rotated results for SD6, because these are the results that Olsen relies upon. They reflect Olsen's unconventional procedure of adjusting PC scores by adding a constant, so that no negative scores occur and the smallest positive score is +1.

Clearly, the Cargill contract grower poultry litter samples, as well as all other poultry litter samples, have a different principal component composition from the other samples included in Olsen's analyses, particularly for the first two PCs (Figures 3-1 and 3-3). This means that no "poultry litter signature" is seen in the environmental or other samples. The other fact worthy of note is how closely the Cargill contract grower soil samples resemble the reference soil samples. The latter are samples that CDM believed to be unaffected by both poultry litter and cattle manure. In Figure 3-1, the Cargill contract grower samples and the reference samples are indistinguishable for the first two PCs. Even with the addition of a third PC in Figure 3-2, two of the three Cargill contract grower soil samples are indistinguishable from the reference soil samples. Similarly, in Figure 3-3 for his SD6 analysis, the Cargill contract grower soil samples are near the reference soil, and the sample from LAL-16B is indistinguishable from reference soil samples.

3.1.2 Cargill Contract Grower Spring-Water Samples

The spring samples associated with Schwabe's farm are located within subbasin 24. According to Apex, both springs are about 1½ miles upgradient from the poultry houses. Other sample locations included in Olsen's water PCA runs (SW3 and SW17) that are downstream of Cargill contract growers are from other subbasins; specifically, three samples from subbasin 6 and one sample from each of subbasins 4, 7, 14, and 15.

In his report, Olsen identifies one of the spring samples (LAL-16-SP2) as having been affected by cattle. The CDM field notebook states, "many cows in area and in spring channel." This is consistent with the Apex report for this location, which noted that there were about 70 head of cattle present north of the spring when the site was visited and photographed on July 7, 2008. Apex also noted that there was a cattle feeder facility north of the spring and that cattle had access to the area where the spring sample was taken. Furthermore, they noted that the spring and stream locations were in a low area and received runoff from the surrounding hills. In Olsen's Figure 6.11-25, LAL-16-SP2 is the sample with the highest PC2 score and clearly has a different composition from the other samples in that figure.

Olsen's report does not identify the other spring sample (LAL-16-SP1) as being affected by cattle. However, the CDM field notebook states "cows in area." Furthermore, when Apex visited this location, also on July 7, 2008, they noted about 100 head of cattle and cattle manure south of the spring sample location. Apex further noted that there was a mineral feeder for cattle about 20 feet from the stream, and that cattle had access to the stream and spring. The LAL-16-SP1 sample location is in a low-lying ravine that is also subject to runoff from the surrounding terrain.

In any case, based on the PCA loadings from SW3 and SW17, sample LAL-16-SP1 does not resemble Olsen's poultry signature, because many of the important analytes were not detected.

Review of the analytes with large positive loadings for PC1 from his SW3 run shows that four of the top six most heavily weighted were not detected in LAL-16-SP1. The analytes not detected are total copper, total organic carbon, total phosphorus, and total aluminum. Similarly for PC1 from his SW17 run, four of the top ten analytes with the largest positive loadings (including the second-largest) were not detected. In this case, the analytes not detected include total phosphorus, total organic carbon, total aluminum, and total dissolved phosphorus.

Additionally, the LAL-16-SP1 sample was non-detect for salmonella species, *staphylococcus aureus*, brevibacteria 16S rRNA, nitrate+nitrite as nitrogen, and a number of other parameters. The failure to detect nitrate+nitrite as nitrogen at a detection level of 0.1 mg/L is particularly striking. Not only does this analyte have a significant loading for PC2 in both the SW3 and SW17 analyses, but also, if turkey litter were affecting this spring, one would expect increased nitrogen levels.

Similarly, the Geoprobe® groundwater sample associated with the Schwabe farm (GP-GW-10) does not resemble the loadings on PC1 from the SW17 run, the water analysis that included groundwater samples. In particular, of the seven largest loadings, three are not detected, including the second-largest loading for total phosphorus. The other analytes with large loadings but not detected include total iron and total aluminum.

Table 3-2 summarizes these comments regarding samples associated with Cargill contract growers.

Table 3-2. Conclusions regarding samples from Cargill contract growers' facilities used in Dr. Olsen's analyses

Sample Type	Grower		Comment
	Schwabe	Masters	
Poultry Litter	FAC-08	FAC-14	-
Surface Soil	LAL-16-B, LAL-16C, LAL-16D	-	Samples similar to reference (background) soil samples.
Groundwater (Geoprobe®)	GP-GW-10	-	Concentrations differ from PC1 loadings, with nondetect results for many of the highest loading analytes.
Springs	LAL-16-SP1	-	Likely affected by cattle; concentrations differ from PC1 loadings with non-detect results for the highest loading analytes.
	LAL-16-SP2		Affected by cattle.

In summary, Olsen collected very few Cargill contract grower–specific samples and used only a subset of the resulting data in his analyses. At the one farm where he did collect environmental samples, the number of samples was inappropriately small for the size of the farm. His failure to collect edge-of-field samples or to use groundwater data means that his pathway analysis is incomplete. Further, the data he did analyze do not support allegations of environmental impacts due to turkey litter, because: (1) Cargill contract grower soil samples are consistent with reference (background) samples; (2) the presence of cattle at both spring locations confounds any conclusions, and (3) the spring sample he identified as unaffected by cattle, as well as the Geoprobe® groundwater sample, do not show his supposed "poultry litter signature" based on PC loadings.

3.2 Downstream and Downgradient Samples

In Section 5, I present a multimedia PCA based on samples identified by Olsen as usable. In the results for this analysis, I have identified the Schwabe samples and the sole Masters sample, as well as samples downstream and downgradient of Cargill contract growers' locations that could potentially be affected. The samples used in my analysis are shown in Table 3-3 below. The purpose of identifying locations downstream and downgradient of Cargill contract growers is to see if there is any evidence that samples from these locations differ significantly from reference (background) samples.

Table 3-3. Sample locations downstream or downgradient of Cargill contract growers

Medium	Location	Cargill Contract Grower Upstream or Upgradient	Number of Samples used in PCA Analysis
Springs	SPR-005RPH051206	Bishop	1
	SPR–Anderson	Lester	1
Surface water	BS-62A	Moua	1
	RS-72	Jim Reed (J&J Farm)	1
	RBS–0000109; RS-109	Biggs	2
	RBS–0000148	Breeder 5	1
	RBS-0000150; RS–150	Breeder 5	2
	RBS–0000395	Robert Fisher (King Farm – Hancock Holdings)	1
	RS-399	Bickford	1
	RS-Ballard	Bickford	1
Sediment	SD-033	Biggs	1
	SD-062	Edwards	1
	SD-083	Breeder 5	1
	SD-210	Mitchell; Hurt	1

5 Multimedia Principal Component Analysis

As noted in previous sections, there are many flaws in Olsen's selection of analytes and samples, as well as in his actual calculations. In my opinion, some of these flaws are fatal; for example, they involve serious mathematical errors and identification of natural soil components as related to poultry litter. However, in this section, I put those flaws aside in order to show that a multimedia PCA, when run correctly and interpreted properly, leads to entirely different conclusions from those presented by Dr. Olsen.

Olsen keeps PCA of solid and liquid samples separate. However, there is no reason to do this, particularly if he believes that there is a consistent poultry litter "signature" that spans from poultry litter to edge-of-field, groundwater, springs, and surface water. PCA of multiple media are not uncommon in the literature.[10] This section describes a multimedia analysis based on the same data as used by Olsen.

Analytes were considered for inclusion in the multimedia PCA if they were measured in all media (both solid and liquid).[11] This excluded, for example, grain size measurements only possible for solid media and dissolved parameters only measurable in liquid media. Samples were included only if more than 50 percent of the analytes were detected. Multiple results for the same sample for the same analyte were averaged (non-detected results included at half the detection limit), regardless of whether detection limits were above detected results. A result was considered non-detect only if all results for that analyte and sample were non-detect. If at least one result was detected, then the average was treated as a detected result.

Parameters measured in both liquid and solid media include total metals (aluminum, arsenic, barium, calcium, copper, iron, potassium, magnesium, manganese, sodium, nickel, and zinc), nitrogen, total phosphorus, bacteria (total coliforms, *e. coli*, *enterococci*, and fecal coliforms), and pH. Results are shown in Figures 5-1 and 5-2. To distinguish this multimedia PCA from Olsen's more limited PCA, I use the terms "MM-PCA" and "MM-PC." Each sample in this analysis is standardized to reflect the percent contribution of each metal to the total metals, the percent nitrogen and percent phosphorus to their sum, the percent contribution of each bacterium to the total bacteria, and pH as is.[12] In this manner, the magnitude of concentrations does not affect the variability.

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10 For example: H. Fiedler, C. Lau, L,-O. Kjeller, and C. Rappe, Patterns and sources of polychlorinated dibenzo-p-dioxin and dibenzofuran found in soil and sediment samples in southern Mississippi, Chemosphere **32**, 421-432 (1996); or R.J. Wenning, D.J. Paustenbach, M.A. Harris, and H. Bedbury, Principal components analysis of potential sources of polychlorinated dibenzo-p-dioxin and dibenzofuran residues in surficial sediments from Newark Bay, New Jersey, Arch. Environ. Contam. Toxicol. **24**, 271-289 (1993).

11 Dissolved phosphorus and sulfate were measured in both solid and liquid media but were excluded from analysis. Dissolved phosphorus duplicates total phosphorus, which was measured in more samples. Inclusion of sulfate in the analysis resulted in only one stream sediment sample analyzed. Results, including sulfate (i.e., excluding all but one sediment sample), are unchanged from those presented here.

12 For a discussion of the so-called "proportion" method, see: S.M. Mudge, op. cit.

5.1 Origins of Sample Variability

With regard to Figures 5-1 and 5-2, the first three MM-PCs account for 58.5% of the total variability among the samples analyzed, with the first two MM-PCs accounting for 49.1%. MM-PC1 distinguishes primarily between media, liquid versus soil and sediment. This division is attributable primarily to aluminum, iron, manganese, barium, and calcium. The soil and sediment samples contain a larger percent of the total metals from aluminum, iron, barium, and manganese, and a smaller percent contribution from calcium, than the liquid samples. In contrast, the liquid samples generally contain less than 1% contribution to total metals from aluminum, iron, barium, and manganese, and contain generally greater than 80% contribution from calcium. As would be expected, the edge-of-field samples lie between the soil samples and the downstream samples, presumably reflecting the fact that these liquid samples have high dissolved and total solids contents.

MM-PC2 defines differences among the various solid media, specifically poultry litter, cattle manure, and soil/sediment. Additionally, the SPLP samples are generally separated from other media. These divisions between media are driven primarily by differences in the ratio of nitrogen to total phosphorus. The SPLP samples contain virtually no nitrogen but do contain phosphorus, whereas the soil and sediment samples contain very little total phosphorus but contain nitrogen. The poultry litter and cattle manure samples fall in between, with a mix of nitrogen and phosphorus, not always in the same proportion. Further separation is attributable to differences in the relative proportion of the four bacteria (to the total) and the relative percent contribution of potassium to total metals. Potassium constitutes greater than 35% of the total metals in poultry litter samples and generally less than 30% in cattle manure. Cattle manure contains roughly even proportions of total coliforms, *e. coli*, and fecal coliform bacteria, whereas poultry-litter samples primarily contain *enterococci* and very low proportions of the other bacteria. There is quite a bit of variability among the poultry litter samples, some with bacteria compositions similar[13] to cattle manure and others showing the distinction just described.

MM-PC3 further separates sample groups based on the relative proportions of the three bacteria parameters: total coliforms, *e. coli*, and *enterococci*. Additionally, the higher variability among the poultry litter samples becomes evident in the MM-PC plot of MM-PC1 vs. MM-PC3 (Figure 5-2). MM-PC3 begins to identify differences between flowing water and non-flowing well water, with flowing water generally having higher positive MM-PC3 scores, while many of the non-flowing water samples have negative MM-PC3 scores; however, this distinction is minor in comparison to the differences between the solid media. Although there is not complete separation on MM-PC3, cattle manure and poultry litter generally have very different scores. As with the first two MM-PCs, there is wide scatter in the edge-of-field samples with regard to MM-PC3. However, edge-of-field samples generally have scores that fall between soil samples and surface water samples.

[13] Similar composition does not mean similar bacteria concentrations.

5.2 Interpretation of the Relationships Among Sample Types

Generally, samples that occupy the same or nearby portions of a PC scores plot are related, and those that occupy different portions of a scores plot are not similar in composition. Dr. Olsen gives an example of this on page 6-56 of his report:

> Most important, the PC1 score vs. PC2 score figure (Figure 6.11-20a and c) shows that the cattle manure plots on the figure in a distinctly different group than the poultry waste…These figures show that cattle manure and poultry waste have different and distinct chemical/bacterial signatures.

Based on the scores plot of MM-PC1 vs. MM-PC2 shown in Figure 5-1, soil samples from the Schwabe farm, along with other soil samples where poultry litter was applied, are indistinguishable from the supposed reference or background soil samples. On Figure 5-2, showing scores for MM-PC1 vs. MM-PC3, the Schwabe samples remain indistinguishable from the reference soil samples. All of this indicates that the composition of the Schwabe soil samples is dominated by native soils (i.e., reference soil).

Sediment samples downstream of Cargill contract growers, as well as other sediment samples, are close in proximity to the cluster of soil samples in Figure 5-1; in general however, they lie between the soil samples and the surface-water samples. This pattern is retained on the MM-PC1 vs. MM-PC3 plot (Figure 5-2), although some of the sediment samples (including the Schwabe samples) are like the reference soil samples with lower values of MM-PC3. This indicates that the sediment samples are also primarily composed of native soils.

Edge-of-field samples are broadly distributed with regard to MM-PC1 and MM-PC2 in Figure 5-1, with some occupying the region between cattle manure/poultry litter samples and surface-water samples, and some in the region between soil/sediment samples and surface-water samples. As noted earlier, there are no edge-of-field samples for the Cargill contract growers.

The cattle manure and poultry litter samples occupy fairly distinct regions of the MM-PC1 vs. MM-PC2 plot in Figure 5-1. However, the two edge-of-field samples from cow pastures (with no poultry litter applied) are indistinguishable from the edge-of-field samples from locations where poultry litter was applied. This holds true for the MM-PC1 vs. MM-PC3 plot also (Figure 5-2). In addition, the SPLP samples for cattle manure overlap with the edge-of-field samples in Figures 5-1 and 5.2. These observations suggest that some edge-of-field samples are affected by cattle manure.

The surface-water samples, including those downstream of the Cargill contract growers and the WWTP samples, are tightly grouped with regard to all three MM-PCs (Figures 5-1 and 5-2). All of these samples have MM-PC scores that are clearly different from the poultry litter samples. Some of the spring and groundwater samples are also in this group, but a few, including the Schwabe samples, are characterized by larger values for MM-PC1. As discussed in Section 3, at least one of the spring samples associated with the Schwabe farm is affected by cattle. The other spring sample and the Geoprobe® groundwater sample have non-detected concentrations for a number of important analytes. In any case, spring and groundwater samples are also clearly distinct from the poultry litter samples.

In summary, all of these results demonstrate that using Dr. Olsen's "pathway analysis," there is no unique chemical signature that passes through the media pathway. Instead, the "signature," as defined by the MM-PCA scores plots, changes continuously along this pathway from medium to medium. The multimedia analysis implicates native soils and cattle manure as likely sources of the analytes indicated as important by Dr. Olsen. In particular, for the sole Cargill contract grower where environmental data were collected, Mr. Schwabe, there is no evidence of chemical or bacterial composition related to poultry litter either in onsite groundwater or downstream of this farm.